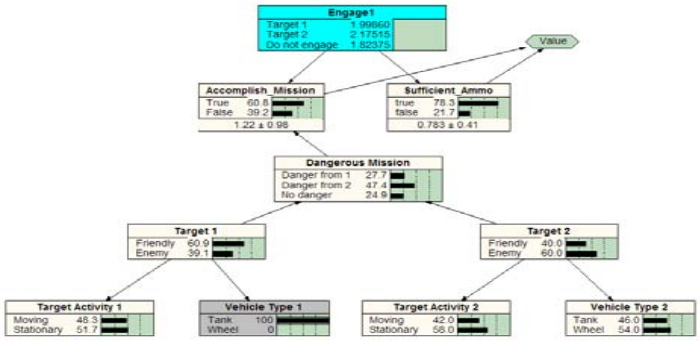
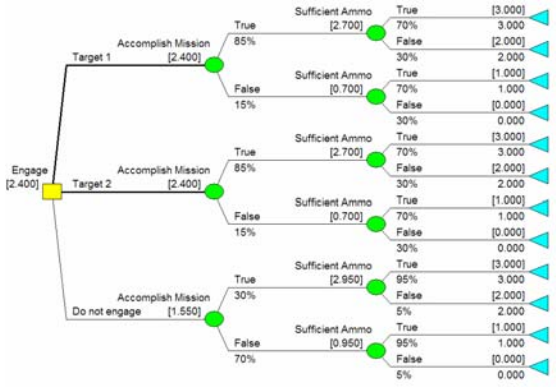
“Validating the Performance of Networks Used to Model Decisions Involving the UAV”

Gerald Kobylski
Greg Graves
Hise Gibson
Brian Souhan
Randal Hickman
Randy Boucher

Dennis Buede
Michael Cassidy





Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 JUN 2008	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Validating the Performance of Networks Used to Model Decisions Involving the UAV	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **IDI Innovative Decisions, Inc.**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM202527. Military Operations Research Society Symposium (76th) Held in New London, Connecticut on June 10-12, 2008, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**18**	

Agenda

- Research effort
- What is a Dynamic Decision Network (DDN)?
- Validation of the DDNs

The Sponsors of the Research Defense Advanced Research Projects Agency (DARPA)

- Three year seedling study
  - Year 1 – exploratory study
  - Years 2 and 3 – customer focused

- The general problem addressed

What is a DDN?

- A Dynamic Decision Network (DDN) is a computer based decision engine that recommends optimal (or near optimal) alternatives for **recurring dynamic** decisions
  - particularly when it is important to consider uncertainty and multiple competing objectives.

- Examples include:
  - shoot or don't shoot
  - divert a sensor platform or keep it where it is

Two Approaches To Optimizing Dynamic Decisions

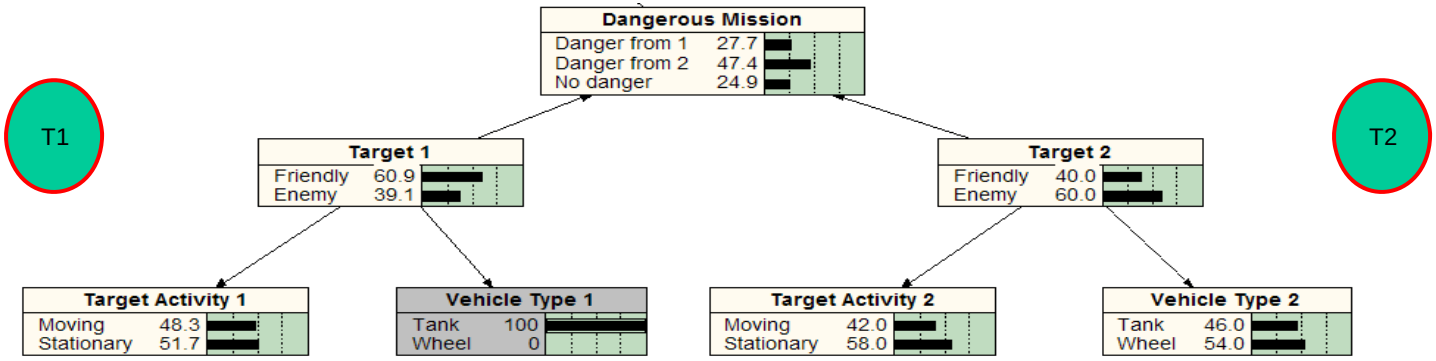
- The hard way (dynamic programming)
  - Solve everything at once by building a model that includes all time periods **AND** all possibilities
  - Problem: the possibilities multiply exponentially
    - "the curse of dimensionality"
- The somewhat easier way (leapfrog) – the DDN approach
  - Make our best decision now

Dynamic Decision Networks (DDNs)

Innovative Decisions, Inc.

- DDNs integrate Bayesian networks (BNs) and influence diagrams (IDs) into the same application in order to optimize the synergy between these techniques.
- We are developing software around a current software package (Netica) to perform the necessary computations.
- Short examples of BNs and IDs will be first given.

Bayesian Network Example (in Netica)



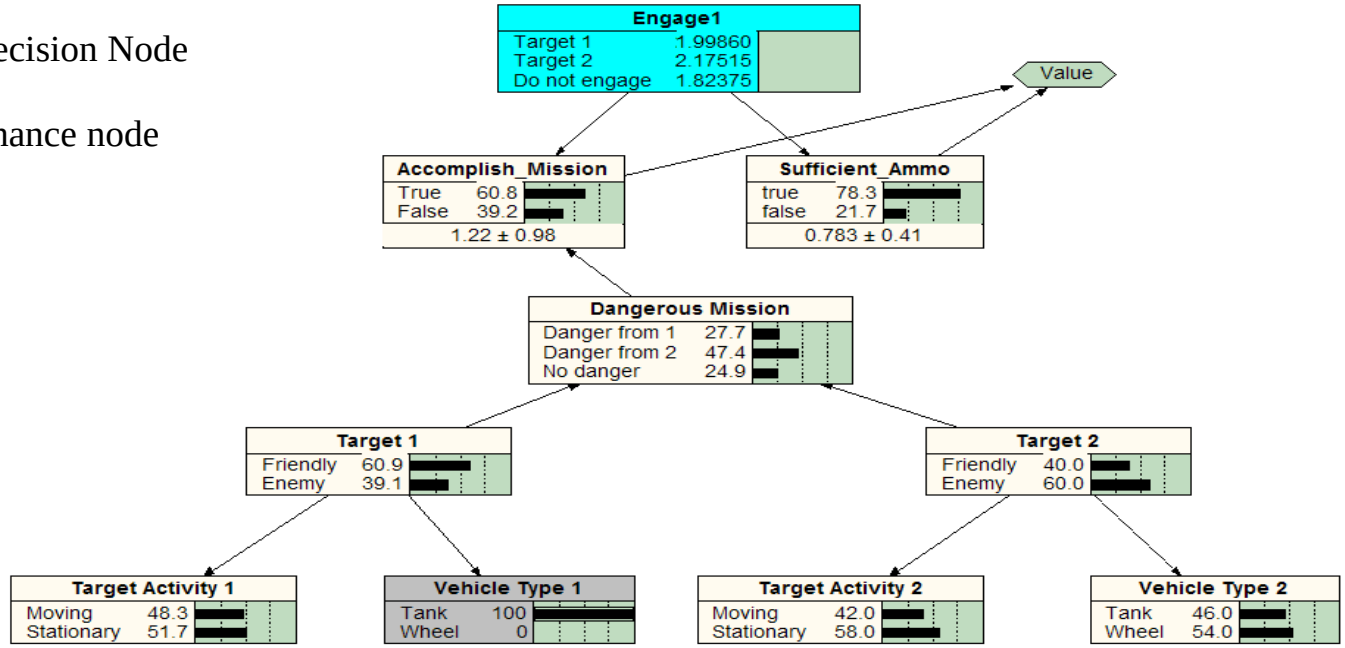
- Structure
  - Nodes and arcs
  - Marginal and conditional distributions
- Purpose

Influence Diagram Example (in Netica)

Legend:

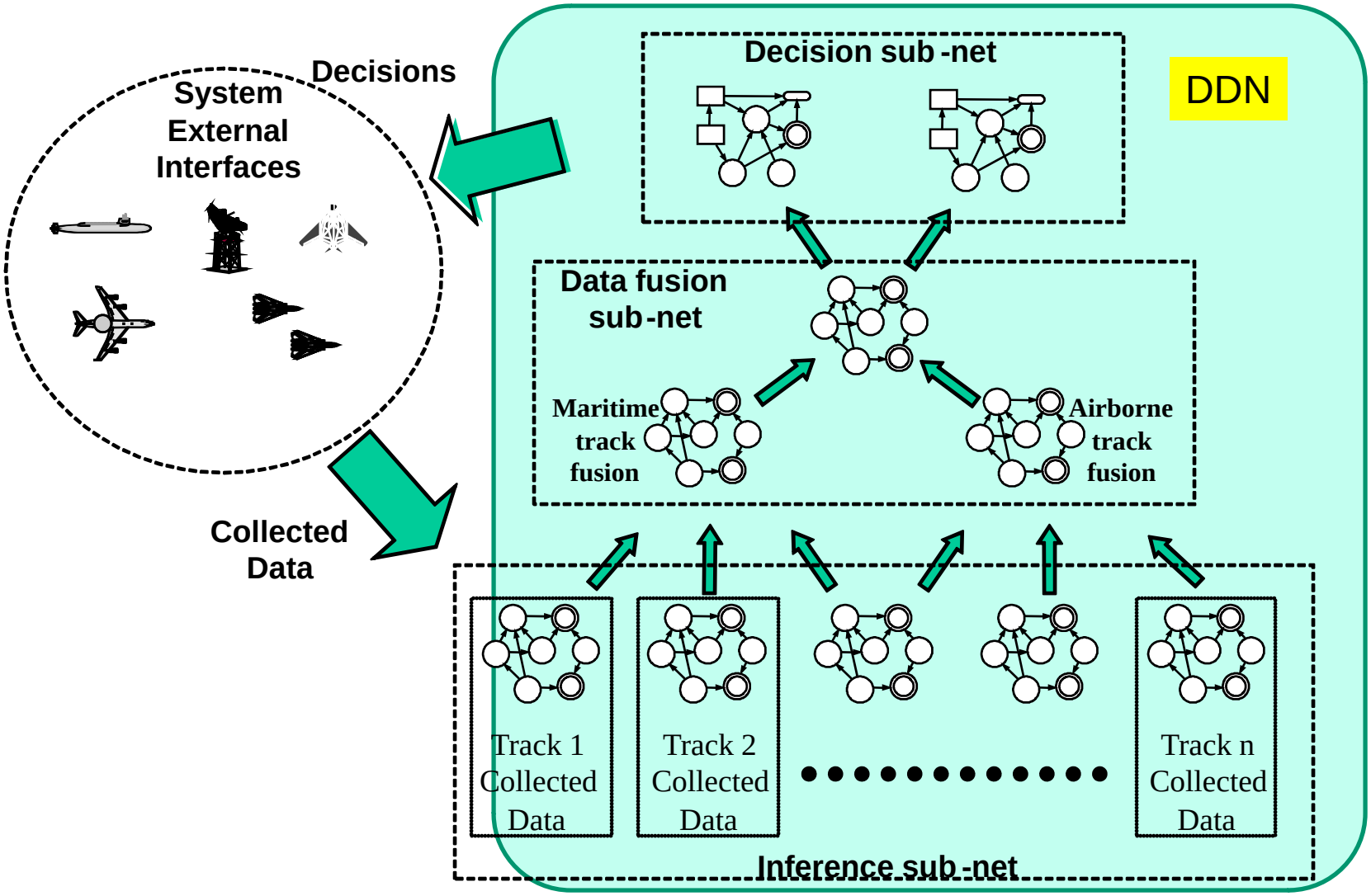
Decision Node

Chance node



- Structure
  - Similar to Bayesian Networks with respect to nodes and arcs
  - Value nodes and decision nodes
- Computes the expected utility of the alternatives across all objectives (Accomplish Mission and Sufficient Ammunition)

Full Representation of a DDN



Computation Time Comparisons (sec)

- The DDNs proved to be exponentially faster than DP as shown in this sample of cases.

Case	slices	alternatives	objectives	targets	reports	DP	DDN
38	3	2	1	1	2	.21	0.09
39	3	3	1	2	1	1.101	0.09
40	3	3	1	2	2	59.766	0.06
41	3	4	1	3	1	51.353	0.09
42	3	4	1	3	2	29875.479	0.12
43	3	2	2	1	1	.24	0.093
44	3	2	2	1	2	.811	0.09
45	3	3	2	2	1	8.242	0.09
46	3	3	2	2	2	517.214	0.09
47	3	4	2	3	1	441.465	0.09
48	3	4	2	3	2	*	0.15

- Computer used - Hewlett Packard Compaq NX7000 with a 1600 MHZ Intel Pentium (R) M processor and 1GB of RAM

FCS System-of-Systems (SoS)

Manned Ground Vehicles (MGV)

Infantry Carrier Vehicle (ICV)

Command and Control Vehicle (C2V)

Centralized Controller

Mounted Combat System (MCS)

Medium Range Munitions

Reconnaissance And Surveillance Vehicle (RSV)

Non-Line of Sight Mortar (NLOS-M)

Non-Line of Sight Cannon (NLOS-C)

Unmanned Aerial Systems (UAS)

Class I UAV

Class IV UAV

Unattended Ground Systems (UGS)

T-UGS

U-UGS

Tactical and Urban Unattended Ground Sensors

Non-Line of Sight Launch System (NLOS-LS)

Unmanned Ground Vehicles (UGV)

MULE-C

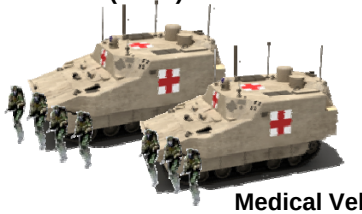
Multifunction Utility/ Logistics and Equipment Countermine and Transport

MULE-T

Armed Robotic Vehicle – Assault (Light) (ARV-A-L)

Small UGV (SUGV)

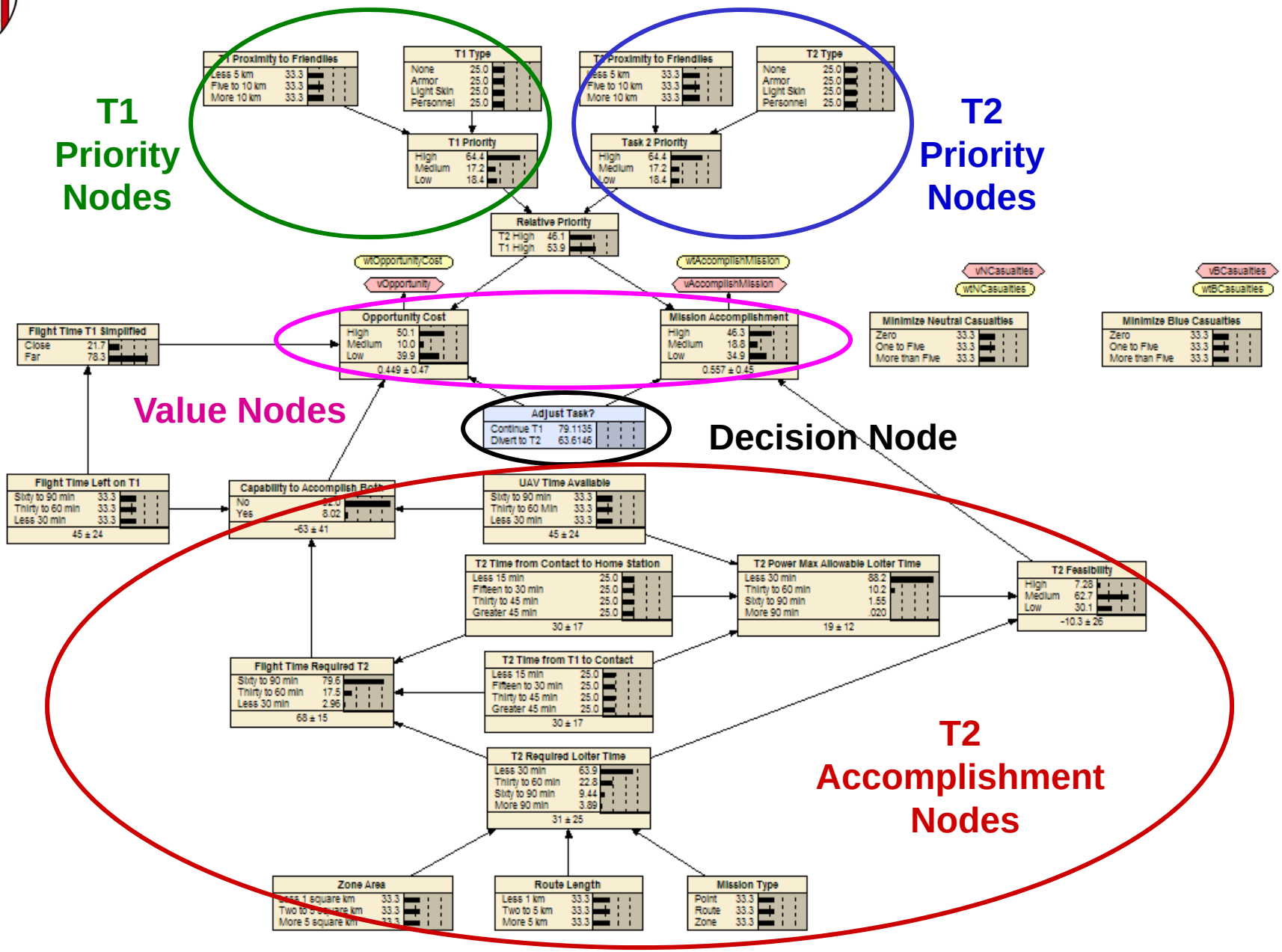
Medical Vehicle Treatment (MV-T)



Medical Vehicle Evacuation (MV-E)

FCS Recovery and Maintenance Vehicle (FRMV)

Continue T1 / Divert T2



Validating the Performance of the DDN

- Can a DDN (decision support tool) adequately replace human decision making on complex, dynamic, repetitive decision tasks that are not mission critical?
- Approach: Perform an experiment with human subjects to determine the adequacy of DDNs as compared to humans.
  - The operator's responsibility is limited to a single UAV.
  - Subjects will be presented a scenario and asked whether UAV should be diverted or should maintain current task
- A panel of experts will determine "correct" decisions for a series of scenarios.
- Analysis will compare subjects' performance against the results from the experts and the DDN against the "correct" decisions

Morphological Box for Scenario Design of Experiment

Factor	Levels			
Fuel	Sufficient to complete current task only.	Sufficient to complete current and new task.	Sufficient to complete current or new task.	
Weather	Clear	Obstructed		
Terrain	Mountainous	Wooded	Desert	Urban
Operator's perception of importance of new task.	Very unimportant	Not important	Important	Very important
cost	High	Medium	Low	

Goal: Performance Measures and Data Collection for N Scenarios

Scenario Fuel Weather Terrain Perceived Importance Cost	Congruence of Operator Decision with DDN Decision [Yes or No]	Congruence of DDN Decision with "Preferred Decision" [Yes or No]	Confidence of Decision Maker [1 to 7 scale]	Time to Make the Decision [seconds]
1 Sufficient fuel to complete current task only. Obstructed Wooded Important High	Yes	Yes	4	20
2 Sufficient fuel to complete current and new task. Clear Urban Very important Low	No	Yes	2	60

Participants and Scenarios

- Participants:
  - Representative of real decision makers
  - Number: at least 25 participants based on a confidence level of 95%
- Scenarios:
  - Minimum number[1]

    = # Levels – # Factors + 1
  - Additional scenarios will improve reliability of sample

Factor	Levels			
Fuel	Sufficient to complete current task only.	Sufficient to complete current and new task.	Sufficient to complete current or new task.	
Weather	Clear	Obstructed		
Terrain	Mountainous	Wooded	Desert	Urban
Operator's perception of importance of new task.	Very unimportant	Not important	Important	Very important
cost	High	Medium	Low	

[1] Hair, Anderson, Tatham, and Black (1998). *Multivariate data analysis*.

Analysis Approach

- Goal: Compare performance of experts, DDNs, and untrained participants.
- Method: Given ordinal-level data, tentatively use a Kruskal-Wallis one-way ANOVA.

Questions / Comments